1.0 Executive Summary of PATH FY98 Final Report

1.1 Objectives of PATH

The Plan for Analyzing and Testing Hypotheses (PATH) is a formal and rigorous program of formulating and testing hypotheses. It is intended to identify, address and to reduce uncertainties in the fundamental biological issues surrounding recovery of endangered spring/summer chinook, fall chinook, steelhead and sockeye stocks in the Columbia River Basin. This process grew out of previous efforts by various power regulatory and fisheries agencies to compare and improve the models used to evaluate management options intended to enhance recovery of these stocks.

The objectives of PATH are to:

1. determine the overall level of support for key alternative hypotheses from existing information, and propose other hypotheses and/or model improvements that are more consistent with these data (retrospective analyses);
2. assess the ability to distinguish among competing hypotheses from future information, and advise institutions on research, monitoring and adaptive management experiments that would maximize learning; and
3. advise regulatory agencies on management actions to restore endangered salmon stocks to self-sustaining levels of abundance (prospective and decision analyses).

PATH products are reviewed by an independent Scientific Review Panel (SRP).

1.2 PATH Accomplishments During Fiscal Year 1998

PATH has made significant progress on all three of these objectives during FY1998. Highlights of PATH activities during the last year include:

- a workshop in October 1997 to evaluate and refine preliminary prospective analyses for spring and summer chinook
- publication of the *Preliminary Decision Analysis Report on Snake River Spring/Summer Chinook* [Marmorek and Peters (eds.)] in March 1998
- publication of *Retrospective and Prospective Analyses of Spring/Summer Chinook Reviewed in FY1997,* in April 1998
- development and refinement of fall chinook passage and life-cycle models, and assembly of fall chinook spawner-recruit data, during February-July 1998
- a preliminary assessment of the effects of management action on fall chinook in August, 1998
- revised *Executive Summary of the Preliminary Decision Analysis Report*, distributed to the Implementation Team on August 4, 1998
- the PATH Weight of Evidence Process to compile and assess the evidence for and against key hypotheses affecting the spring/summer decision analysis during May to August, 1998

- publication and SRP review of the *PATH Weight of Evidence* report (WOE) in August 1998
- a workshop with the SRP to document their best judgements on the relative likelihood of key hypotheses, and a workshop report published in September 1998. This report also included SRP recommendations to PATH regarding the application of experimental management and relevant modeling approaches (objective 2)
- assessment of additional actions both spring/summer chinook and preliminary assessment of options for fall chinook during September-October 1998
- completion of qualitative assessments of the effects of actions on Snake River steelhead (March - October 1998)
- development of historic assessments of SARs (smolt to adult returns) for Snake and Upper Columbia steelhead, and Snake River spring chinook (December 1997 to May 1998)
- initiated assessments on sockeye salmon (October 1998)
- completion of a discussion paper on applying experimental management to the Columbia River, which builds on the SRP's suggestions in their report from the Weighting Workshop (October 1998)

1.3 Summary of Results of Assessments of Actions

1.3.1 General Approach

PATH retrospective analyses have helped to bring a substantial set of empirical information to bear on alternative hypotheses to explain recent declines in Snake River chinook, and have led to considerable improvements in both our understanding and modeling approaches. In addition, there has been considerable convergence on the historical data sets to use in calibrating and testing models, and on many of the assumptions to be made when projecting future population changes.

The PATH retrospective analyses have also highlighted some major uncertainties in past and current conditions that have yet to be resolved because of incomplete data and differences in interpretation. These uncertainties, along with uncertainties in projecting future conditions, imply that a single management action can have a number of possible outcomes, depending on what is assumed about past, present, and future conditions. This range of possible future outcomes of management actions is best captured by modeling salmon populations under a set of alternative hypotheses about uncertain components of the system.

PATH uses decision analysis techniques as a structured framework for looking systematically at the outcomes of management actions under several alternative hypotheses about biological mechanisms that link actions to possible outcomes. Management actions can then be evaluated on the basis of their outcomes. This approach was recommended by the SRP and by independent scientists within PATH as a tool for explicitly considering uncertainties in the decision-making process, in recognition that decisions cannot wait for all uncertainties to be resolved. Decision analysis is not intended to provide a single answer about stock responses to specific actions; rather, it will show which actions are most robust (or risk averse) to the uncertainties captured in quantitative models. The SRP has also recommended an experimental management approach to further reduce remaining uncertainties.

PATH has developed a quantitative decision analysis framework for spring/summer chinook and a preliminary framework for fall chinook. We have developed a qualitative analysis for steelhead using comparisons of the likely effects of actions on spring/summer chinook as a guide to the probable response of steelhead. We have recently begun to consider how our findings might apply to sockeye.

1.3.2 Management Actions

The PATH decision analysis, under the direction of the Implementation Team, has been focused on the extent to which alternative hydrosystem actions can contribute to preventing extinction and aiding recovery of stocks either listed or proposed for listing, including wild spring/summer chinook, fall chinook and steelhead stocks in the Snake River and mid-Columbia region. PATH is focussed on providing a detailed assessment of hydrosystem alternatives, as called for in the NMFS 1995 Biological Opinion. The effects of habitat and harvest management actions are considered in sensitivity analyses (Section 2.3), with further sensitivity analyses being considered in FY99. We consider the possible effects of current hatchery operations, but do not consider major changes in production levels. We also intend to explore options for an experimental management approach, which varies management actions over time and space (including habitat, harvest and hatchery actions) to test key hypotheses and reduce remaining uncertainties. A discussion of experimental management is included in Chapter 6 of this report.

Table 1.3.2-1 shows the range of alternative hydrosystem actions that have been put forward for consideration. In accordance with the priorities on these actions established by the I.T., we have evaluated seven of these:

- A1 – current hydrosystem operations (under the 1995 Biological Opinion Interim Action)
- A2 – A1+ maximize transportation (without surface collectors)
- A2’ – A1+ maximize transportation using surface bypass collectors
- A3 – natural river drawdown of the four lower Snake River dams (Lower Granite, Little Goose, Lower Monumental and Ice Harbor)
- A6 – in-river option (no transportation, no drawdown, flow augmentation as in A1 plus 1 million acre-feet from upper Snake River, and surface bypass). This option has not yet been fully developed, so we have done a preliminary qualitative assessment of its probable effects on spring/summer chinook, relative to the other actions. Further analysis for fall chinook and spring/summer chinook is under consideration.
- A6` – A6, but with flow augmentation as in A1, reduced by 427,000 acre-feet
- B1 – natural river drawdown of the four lower Snake River dams **and** John Day dam

Table 1.3.2-1: Hydro system management actions examined by PATH. The A6 and A6‘ options have not yet been quantitatively defined to the same extent as the other options.

Scenario	Flow Augmentation		Drawdown of four Snake River Dams	Drawdown of John Day Dam	Transportation	Major system improvements (1)
	Columbia	Snake				
A1	X	X	-	-	X	- (2)
A2	X	X	-	-	X	- (3)
A2’	X	X	-	-	X	X
A3	X	X	Natural River	-	-	-
A6	X	X(4)	-	-	-	X
A6’	X	X(5)	-	-	-	X
B1	X	X	Natural River	Natural River	-	-

(1) Major system improvements include extended screens and/or surface bypass and/or gas abatement and/or increased spill.
(2) A1 uses current transportation rules.
(3) A2 maximizes transportation using current system configuration.
(4) Dworshak water plus 1 million acre-feet from Snake River.
(5) Dworshak water, but no additional Snake River water.

1.3.3 Uncertainties in the Response of Populations to Management Actions

The response of fish populations to hydrosystem management actions under consideration is determined by the hypothesized effects of these actions, and of external environmental influences, on fish at all stages of their life cycle. For spring/summer and fall chinook, we have identified specific alternative hypotheses about:

- factors that affect survival of juveniles through the hydrosystem;
- timing and magnitude of the effects of drawdown on juvenile survival; and
- factors that affect survival of fish outside of the hydrosystem, including climate, harvest and habitat conditions.

Many of these uncertainties cannot be resolved with existing information. The SRP recommended that PATH assess the benefits and risks of an experimental management approach in reducing the key remaining uncertainties. Uncertainties are considered in a less explicit way for steelhead and sockeye.

1.3.4 Performance Measures Used to Assess the Outcomes of the Options

The outcomes of alternative hydro management actions are presented in terms of various measures of how well they perform, both relative to each other and with respect to absolute criteria. Because the primary goal is to determine the hydrosystem actions that should be taken to prevent extinction and lead to recovery of endangered stocks, we focus here on the National Marine Fisheries Service (NMFS) jeopardy standards that were considered in the 1995 Biological Opinion. These standards provide an indication of the ability of actions to increase the spawning abundance of stocks to levels that will avoid extinction and lead to recovery, over short (24 years) and longer (48- and 100-year) time periods. The standards are described in detail in Appendix D of the *PATH Preliminary Decision Analysis Report*, and summarized below.

NMFS Jeopardy Standards

The way in which a specific hydrosystem action affects the chance of an individual spawning stock going extinct is difficult to estimate, because there may be unpredictable population behaviors at low abundance. The performance measure we use to describe the possibility of extinction here is called a "Survival" standard. This was developed by the Biological Requirements Working Group (BRWG 1994), and has largely been accepted by NMFS for use in Snake River chinook salmon jeopardy determinations. The Survival standard is the fraction of time during many simulations that the spawning abundance of a stock is above a specified low threshold. For the seven spring/summer chinook stocks we examined in the Snake River Basin, the threshold level used is either 150 spawners or 300 spawners depending on the characteristics of the stock and the stream. These levels were chosen because below these levels, spawner/recruit relationships are poorly known and unpredictable changes in population behavior are likely to occur. For Snake River fall chinook (one stock only) a provisional survival standard of 300 spawners was developed by the BRWG, and adopted by NMFS in their 1995 Biological Opinion. The survival standard is calculated for simulations run over 24 and 100 years. Survival thresholds were developed by the BRWG specifically for spring/summer chinook, and provisionally for fall chinook, but have not yet been extended to steelhead or sockeye. We therefore use simpler approaches for steelhead and sockeye.

The effect of a certain hydrosystem action on the chance of a spawning stock recovering is described by the "Recovery" standard chosen by the BRWG, who proposed 24- and 48-year recovery standards. The 1995 Biological Opinion used only the 48-year recovery standard: this is the fraction of simulation runs for which the average spawner abundance over the last 8 years of a 48-year simulation is greater than a specified level. For spring/summer chinook stocks the specified level of abundance (the recovery level) is different for each stream, and is 60% of the pre-1971 brood-year average spawner counts in each stream. We use the average abundance of spawners over the last eight years as an index of escapement to compare with the specified recovery level for each stock.[1] For fall chinook, the recovery standard used in the NMFS 1995 Biological Opinion was 2500 spawners. To date no recovery standards have been defined for steelhead or sockeye.

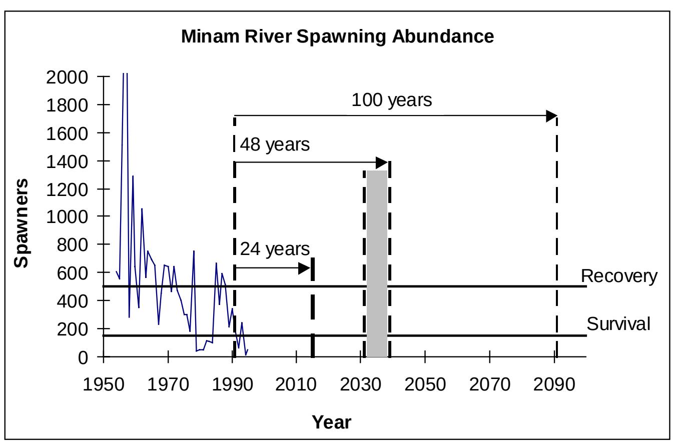

Figure 1.3.4-1: Recent trends in Minam River spawning abundance to 1991, relative to its survival (150) and recovery (450) levels of spawners under NMFS jeopardy standards. Also shown are the 24-, 48-, and 100-year periods for future projections.

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[1] We compare the *geometric mean* of simulated future escapements with the arithmetic mean of historical abundances (recovery standard). This difference in summary statistics is recognized, but we use this method because the recovery levels are generally accepted targets, and the geometric mean is an accepted summary statistic for skewed distributions such as abundances of fish over time.

Both jeopardy standards apply to individual stocks. However, the overall performance of the system under different options needs to be described in terms of how each option affects a representative sample of all listed stocks in an Evolutionarily Significant Unit (ESU). To apply these performance standards to a number of stocks, NMFS has defined an overall Jeopardy Standard which considers, among other things, these model-derived probabilities as measures of the ability of an action to prevent extinction of an endangered stock. To meet this standard, an action must result in a "high percentage" of available populations having a "high likelihood" of being above the survival threshold level and a "moderate likelihood" of being above the recovery level. "High" and "moderate" likelihoods have been informally defined as being 0.7 for survival standards, and 0.5 for recovery standards. NMFS has defined "high percentage" of stocks as 80% of the available populations. For the cases in which we are focused on the seven Snake River index stocks, this means that for an action to be considered to have met the overall jeopardy standard, the action must result in six stocks having a probability of 0.7 or greater of being above the survival threshold and a probability of 0.5 or greater of being above the recovery threshold.

Actions can be ranked according to their relative performance (i.e., actions with high probabilities of meeting the standards have greater biological benefits than actions with low probabilities), or according to some criterion (e.g., actions must have at least a 0.50 probability of meeting all of the standards). The establishment of such a criterion is a question for policy-makers, and we have not attempted to define one here.

Box 1-1 outlines how we compute and display the probability that a given action will meet one of the three NMFS standards. Since there are three standards, there are three such probabilities. The overall probability of meeting all three NMFS standards is determined by the lowest of the three probabilities. The following section summarizes these overall probabilities for each action and species. Actual calculation of the probabilities has only been completed for spring/summer and fall chinook, for all actions except for A6 and A6'. Results presented for A6/A6' and for steelhead and sockeye are based on qualitative comparisons, as described in the main report.

An important point to note about the probabilities of meeting the standards is that these probabilities explicitly incorporate the uncertainties we have defined (Box 1-1). That is, the probabilities are based on outcomes arising from all of the alternative hypotheses and the various combinations of those hypotheses. Therefore, actions with high probabilities meet the standards under a broad range of possible hypotheses about future conditions (a robust action), while actions with low probabilities meet the standards under a narrower range of hypotheses.

The probabilities also incorporate weights on the alternative hypotheses that reflect the relative likelihood of being true. Outcomes derived from hypotheses that have a high likelihood of being true contribute more to the overall probability of meeting the standards than outcomes that are derived from hypotheses with a lower likelihood of being true. Weights on hypotheses can be developed through a comprehensive review of the evidence for and against alternative hypotheses, as we have done for spring/summer chinook through the Weight of Evidence process. However, in the absence of such process, the best we can do is to place equal weights on all of the hypotheses to reflect our lack of knowledge about which hypotheses are more likely than others. This is the case for fall chinook, because we have not yet gone through a Weight of Evidence type of process for that species.

1.3.5 Summary of Overall Results for All Species

The hydrosystem management actions were evaluated across a broad range of uncertainties. The natural river actions (A3, B1) exhibited the most robust response across these uncertainties (i.e., those considered to date). For all species, A3 and B1 produce higher biological benefits than the other actions (the rank order of A3 and B1 depends on the delay in implementing Snake River drawdown).

Overall results for all species are summarized in Table 1.3.5-1 and Figures 1.3.6-1 and 1.3.6-2. This summary of results shows the overall assessments of actions, but the results are based on a much more detailed set of assumptions and calculations. We urge the reader to read the remainder of the report to fully understand how the summary results were derived. In general, the relative performance of different actions is a more reliable and consistent outcome of our analyses than the absolute probabilities, which are more sensitive to different assumptions.

We stress that the analyses for spring/summer chinook have been much more extensive and detailed than our fall chinook analyses. For spring/summer chinook we had spawner/recruit data for multiple upstream stocks, directly applicable transport studies, and many years of juvenile and smolt-to-adult survival rate estimates. The SRP reviewed numerous retrospective and prospective products over a period of two years, prior to PATH performing a detailed decision analysis, using two fundamentally different life-cycle models. We produced *a Weight of Evidence* report with 25 separate submissions to evaluate alternative hypotheses, and the SRP performed a formal weighting process. In contrast, for fall chinook, we have only a short time series of juvenile passage data available, no directly applicable transport study results, and a shortage of data on downstream stocks for use as controls in life-cycle modeling. PATH has only worked on fall chinook for only about six months, and the SRP has not yet reviewed the fall chinook work products.

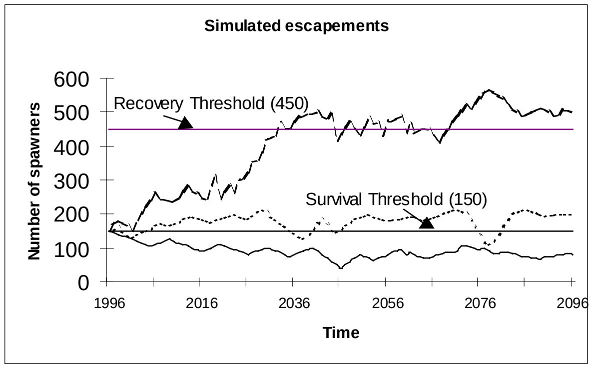
For spring/summer and fall chinook, the values reported are the overall probabilities of meeting all of the standards (fractions of runs), as described in Box 1-1. We report the probabilities for spring/summer chinook with all hypotheses equally weighted (first row), and using the mean of the weights developed by the SRP through the weight of evidence process (second row). Probabilities for fall chinook are with all hypotheses equally weighted. A1 was not run for fall chinook because the A1 system configuration and level of transportation was virtually identical to that of A2. Results for A3 for spring/summer chinook are reported separately for either a 3-year or an 8-year delay before the Snake River dams are removed. Both options were explored for fall chinook as well, but only the mean of these two values is reported here. Results for B1 on average assume a 5.5-year delay before removal of Snake River dams (average of 3 and 8 years), and a 12.5-year delay before removal of John Day dam (average of 10 and 15 years).

One of the reasons for considering multiple species in evaluating the effects of management actions is to uncover any situations where an action may be preferred for one species but is detrimental to another. In reviewing the results summarized in the table above, there do not appear to be any of these situations. Again, we leave it to policy-makers to decide whether the biological benefits of any of these actions are “high enough”, given other factors that may influence the final decision.

Box 1-1. General steps involved in calculating the probability that a given hydrosystem action will meet a NMFS standard. This example assumes all hypotheses are equally weighted.

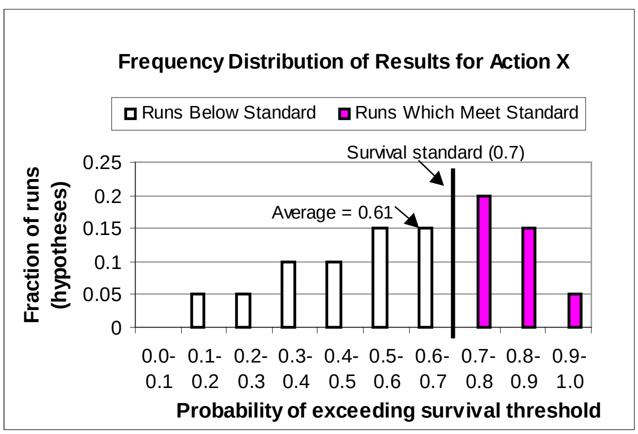
1. Select one combination of hypotheses for this action (a "run").

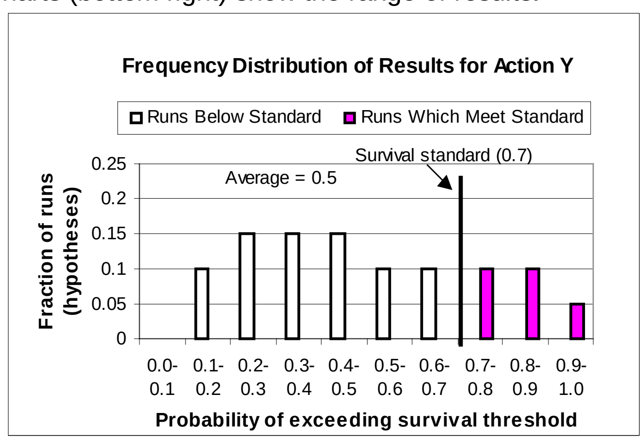
2. Simulate many possible future trajectories for this combination of hypotheses, over the next 100 years, given uncertainties in stock productivity, climate etc.

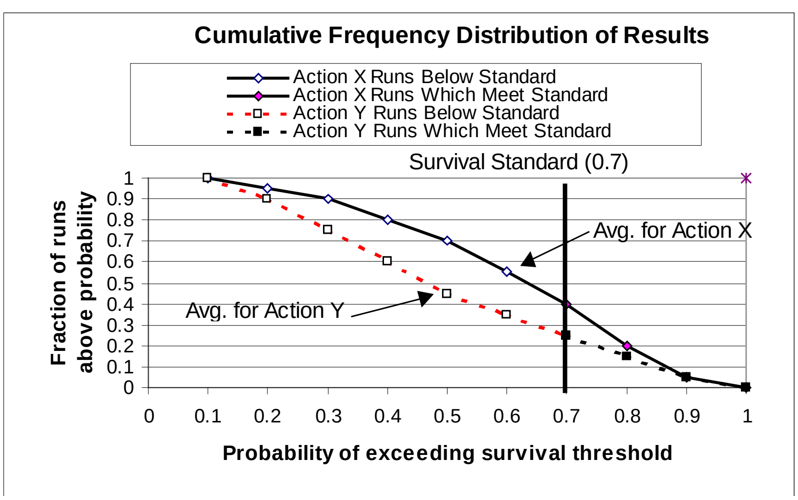


3. Calculate the probabilities of exceeding survival threshold (over 24 and 100 years) and recovery threshold (years 17 to 24, and years 41 to 48).

4. Repeat steps 1-3 for all possible combinations of hypotheses and actions. We want to know the fraction of runs meeting the NMFS standard, and the average probability of exceeding the threshold. These can be displayed in a number of ways. For action X, the fraction of runs meeting survival standard = 0.4 (0.2+0.15+0.05), and average probability of exceeding survival threshold is 0.61. For action Y, the fraction of runs meeting survival standard = 0.25 (0.1+0.1+0.05), and average probability of exceeding survival threshold is 0.5. Cumulative frequency distributions (bottom left) show the fraction of runs above any standard for actions X and Y, and box and whisker charts (bottom right) show the range of results.







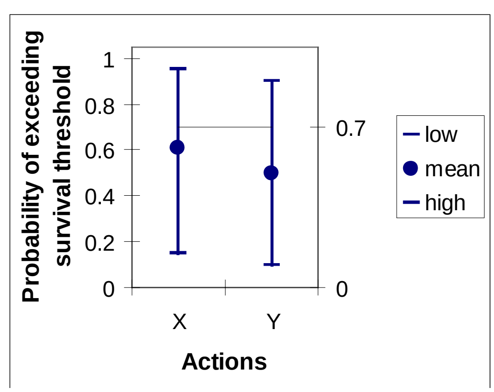


Table 1.3.5-1: Summary of results for all species. Numbers for spring/summer and fall chinook are overall probabilities of meeting all three NMFS standards, computed from the fraction of runs or hypotheses which met all three standards. Actions with high probabilities meet the standards under a broad range of hypotheses about future conditions (a robust action), while actions with low probabilities meet the standards under a narrower range of hypotheses. These results consider only those management actions and uncertainties in the other H's (habitat, harvest, hatcheries) described in Sections 1.3.2 and 1.3.3.

<table>
<tr><th rowspan="2">Species</th><th colspan="6">Actions</th></tr>
<tr><th>A1</th><th>A2</th><th>A2'</th><th>A6/A6'</th><th>A3</th><th>B1</th></tr>
<tr><td>Spring/summer chinook (equal weights)</td><td>0.35</td><td>0.35</td><td>0.37</td><td rowspan="2">A6 obtains 60 to 150% of A2 performance with wide range of assumptions, and 80 to 100% of A2 performance using a "more realistic" set of assumptions.

A6' performs worse than A2.</td><td>0.63 (3-year)
0.47 (8-year)</td><td>0.59</td></tr>
<tr><td>Spring/Summer chinook (SRP weights)</td><td>0.27</td><td>0.25</td><td>0.29</td><td>0.65 (3-year)
0.48 (8-year)</td><td>0.62</td></tr>
<tr><td>Fall chinook</td><td>n/a</td><td>0.15</td><td>0.23</td><td>Analysis not yet completed</td><td>1.00</td><td>1.00</td></tr>
<tr><td>Steelhead</td><td colspan="6">Relative performance of actions for spring/summer chinook applies to steelhead(1)</td></tr>
<tr><td>Sockeye</td><td colspan="3">Less likely to lead to recovery than for spring/summer chinook</td><td colspan="3">Analysis not yet completed</td></tr>
</table>

(1) Actions that meet standards for spring/summer chinook are likely to meet standards for steelhead; actions that do not meet standards for spring/summer chinook may or may not meet standards for steelhead.

1.3.6 More Detailed Performance Measures

Figures 1.3.6-1 and 1.3.6-2 summarize the weighted average probabilities of exceeding specific NMFS survival and recovery thresholds, for both spring/summer chinook and fall chinook. The probabilities of exceeding recovery thresholds show greater discrimination among actions than the survival jeopardy probabilities, for both groups of spring/summer and fall chinook. For spring/summer chinook, the mean SRP weights generated results very similar to applying equal weights (Figure 1.3.6-1). The first part of these charts (i.e., Figures 1.3.6-1a and 1.3.6-2a) show weighted **average** probabilities; the range of probabilities of exceeding survival/recovery thresholds is shown in Figures 1.3.6-1b and 1.3.6-2b.

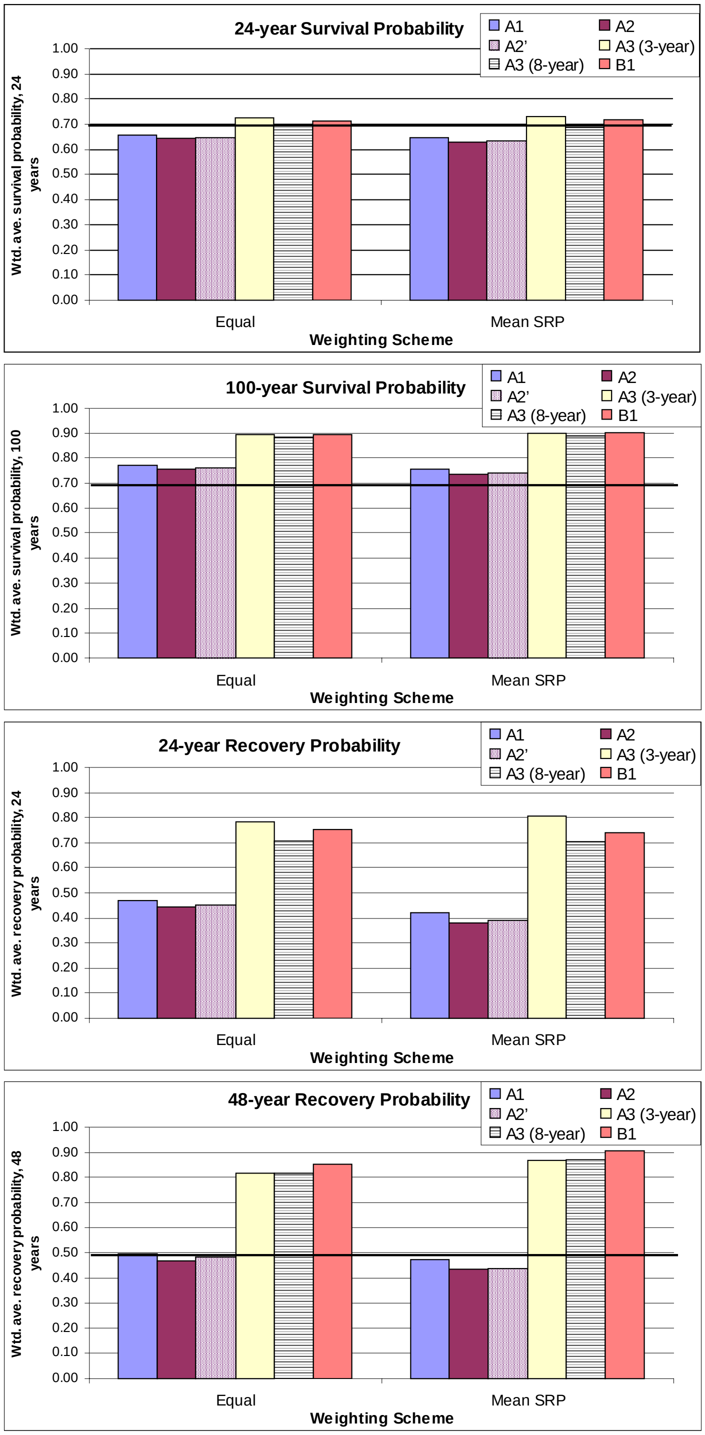


Figure 1.3.6-1a: Average probabilities of exceeding survival and recovery thresholds for spring/summer chinook, using both equally weighted and SRP-weighted hypotheses. Horizontal lines indicate NMFS standard (none for the 24-year recovery probability). These results consider only those management actions and uncertainties in the other H's (habitat, harvest, hatcheries) described in Sections 1.3.2 and 1.3.3.

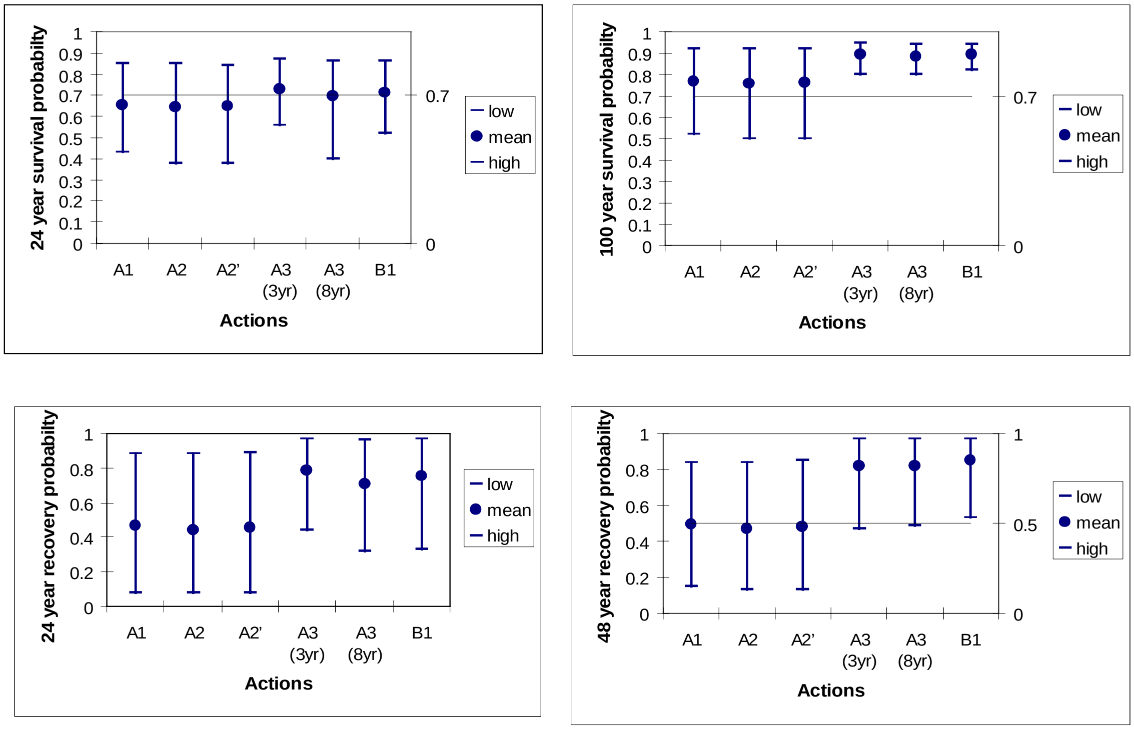


Figure 1.3.6-1b: Lowest, mean and highest probabilities of exceeding NMFS thresholds for survival (top two graphs) and recovery (bottom two graphs) for spring/summer chinook, under six different hydrosystem management actions. Horizontal lines are NMFS standards (none for 24-year recovery probability). Means are calculated weighting all hypotheses equally, and are comparable to those on the left side of Figure 1.3.6-1a. Ranges are unaffected by the assigned weights. These results consider only those management actions and uncertainties in the other H's (habitat, harvest, hatcheries) described in Sections 1.3.2 and 1.3.3.

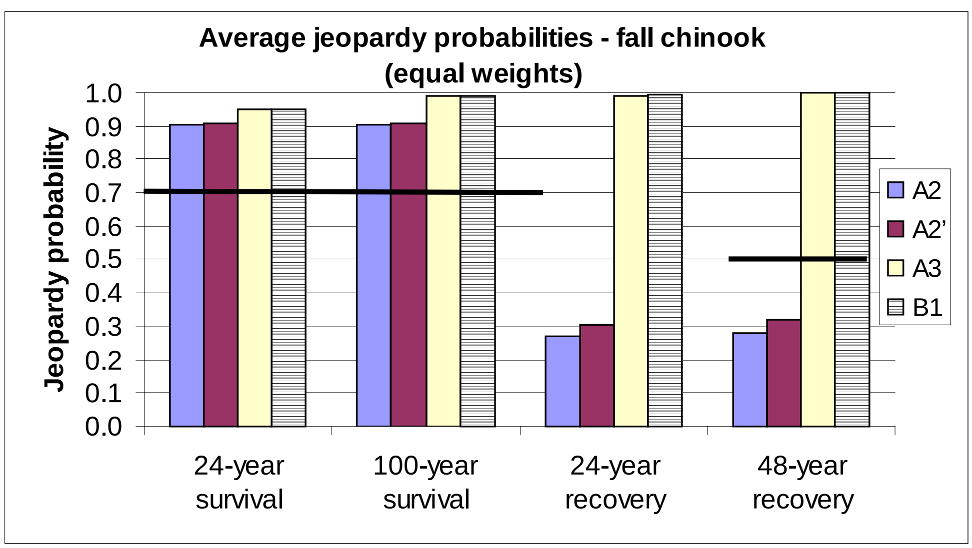


Figure 1.3.6-2a: Average jeopardy probabilities for A2, A2', A3 and B1, using equal weights on all hypotheses.

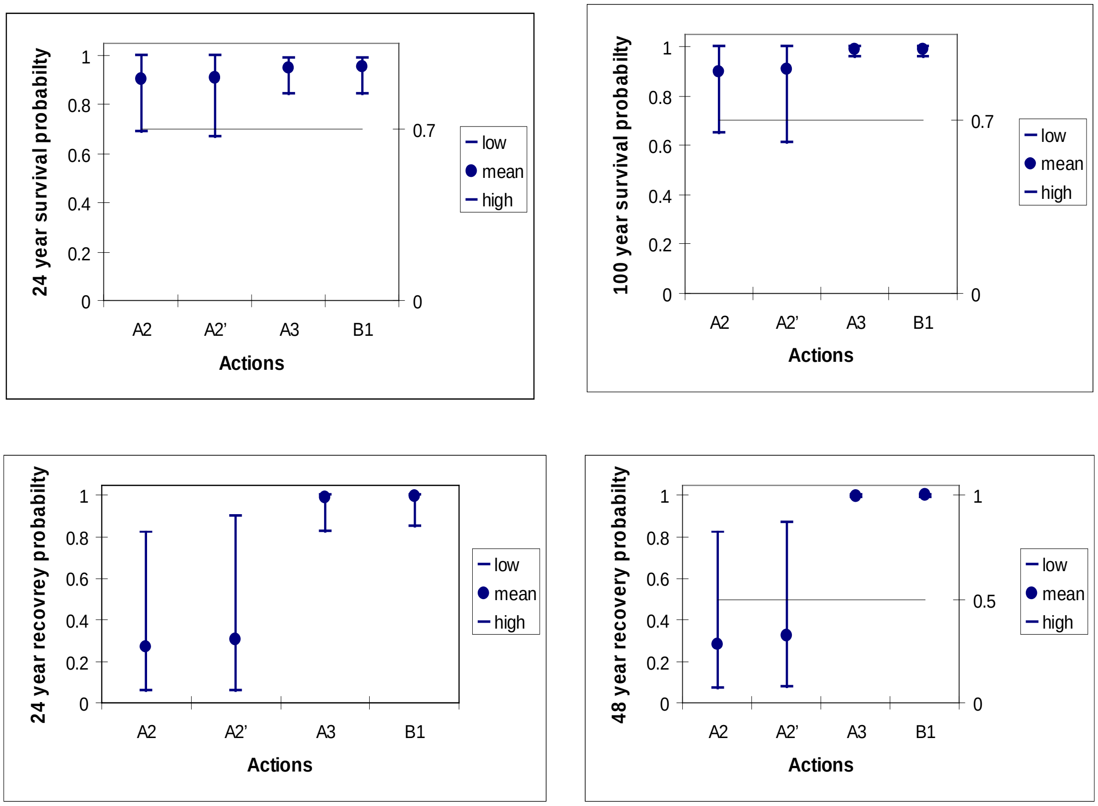


Figure 1.3.6-2b: Lowest, mean (average) and highest probabilities of exceeding NMFS thresholds for survival (top two graphs) and recovery (bottom two graphs) for fall chinook, under four different hydrosystem management actions. Horizontal lines are NMFS standards. Means are computed weighting all hypotheses equally, and are the same as values shown in Figure 1.3.6-2a. These results consider only those management actions and uncertainties in the other H's (habitat, harvest, hatcheries) described in Sections 1.3.2 and 1.3.3.

Smolt to adult survival rates (SARs) estimate survival rates of fish from the time they pass the upper-most dam as smolts to the time they return to that dam as adults. The PATH life-cycle model calculates a median SAR based on many thousands of simulations over a 100-year simulation period. All actions generate SARs that exceed historical estimates (Table 1.3.6-1). Median SAR model estimates to the upper dam were higher for action A3 than for actions A1 and A2. For A3, the median SAR was 4.0%, compared to 2.4% for A1 and 2.3% for A2. Minimum SARs for the three actions were 1.6%, 1.6% and 2.4% for A1, A2 and A3, respectively. Maximum SARs for the three actions were 4.9%, 4.8% and 7.1% for A1, A2 and A3, respectively.

Table 1.3.6-1: Range and median SARs for spring/summer chinook under actions A1, A2, and A3, compared to historical estimates for 1977 to 1994.

	Minimum SAR	Median SAR	Maximum SAR
Historical (1977-1994)	0.2	1.0	2.6
A1	1.6	2.4	4.9
A2	1.6	2.3	4.8
A3	2.4	4.0	7.1

The range of forecasted escapements rapidly increases over the first 30 to 40 years, and then levels out. Figure 1.3.6-3 shows an example of this pattern for one spring/summer chinook stock, Johnson Creek, under different actions. Johnson Creek is frequently the sixth best stock and therefore its escapement values are relevant to the NMFS jeopardy standards. Note that in Figure 1.3.6-3 we have included historical escapement estimates; these past estimates are just one of many possible time sequences which could have occurred. The summary statistics on future projections are summarized from many thousands of possible future trajectories.

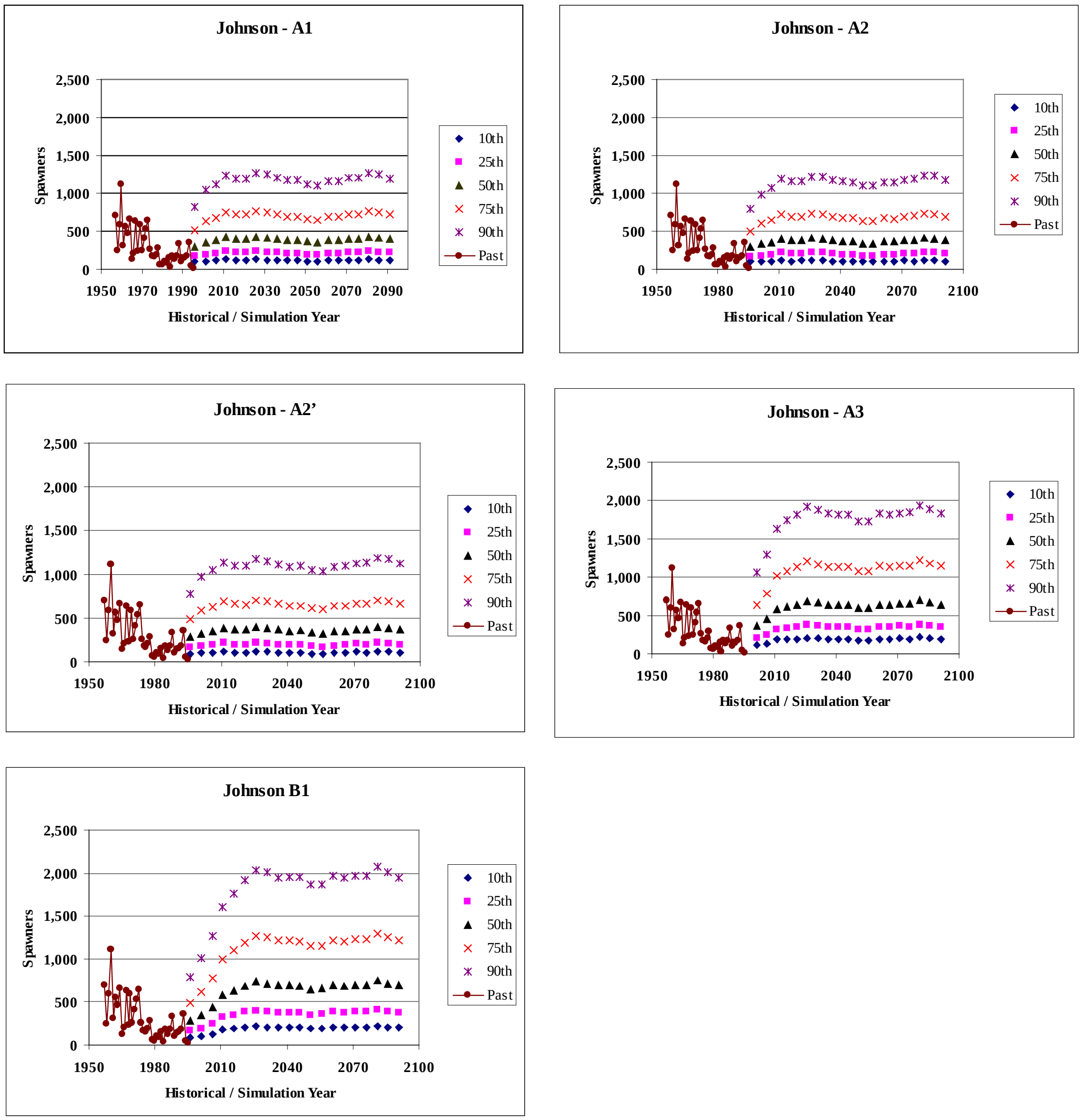


Figure 1.3.6-3: Forecasted range of escapements for Johnson Creek, under different hydrosystem management actions. The points represent the 10th, 25th, 50th, 75th, and 90th percentiles of the forecasted range of escapements in each future year. The past estimates are just one of many possible stock trajectories which could have occurred. The summary statistics on future projections are summarized from many thousands of possible future trajectories. This graph of spawning escapements is not directly comparable to NMFS standards for survival and recovery.

1.3.7 Summary of Sensitivity Analyses

In addition to the uncertainties that are explicitly incorporated into the calculation of probabilities of meeting the standards, PATH has explored the effects of other assumptions on overall results. Many of these have been documented in previous PATH reports. In this report, we have looked specifically at the sensitivity of results to the four factors: habitat, harvest, bird predation in Columbia River estuary, and upstream survival rates. General results are summarized below; more detailed explanation of these factors and their effects on results are in Sections 2.3 and 3.4 of the main report.

1. Management of freshwater spawning and rearing habitat (spring/summer chinook only)

General result: Alternative habitat scenarios (all practical measures taken to protect and restore fish habitat) lead to increases in average jeopardy probabilities for some stocks (Bear Valley, Imnaha, Johnson Flat, Poverty Flat), and reductions for others (Marsh Creek, Minam, Sulphur Creek). It is at first surprising that an improvement in habitat for one stock could reduce the abundance of several stocks. There is however a logical explanation. When habitat improvements lead to larger escapements for stronger stocks, this triggers higher in-river harvest rates for all Snake River stocks, including the weaker stocks, since in-river harvest rates increase as total Snake River abundance increases. As a consequence, all stocks are harvested at a higher harvest rate which can lead to lower escapements than would otherwise be the case. This is particularly true for weaker stocks in pristine habitat (Marsh Creek, Minam, Sulphur Creek) that have zero probabilities of increasing productivity with the increased habitat protection and conservation scenarios.

Overall effects were minor, and did not affect the ranking of actions. Because the analysis was done with a limited set of runs, definite conclusions about the affect of these habitat scenarios on the overall ability of actions to meet the standards (i.e., the fraction of runs in which all of the jeopardy standards are met) are not possible. However, for situations where average jeopardy probabilities are close to the standards with the base habitat scenario, such effects are possible. An analysis with a complete set of runs is required to fully address this question.

2a. Harvest rate reductions (spring/summer chinook)

General result: In-river harvest rates for Snake River spring/summer chinook proceed in a step-wise fashion depending on their abundance (Table 2.3.2-1). Harvest rates have ranged from 3% to 8% since 1975. The effects of harvest rate reductions depend upon the size of the reduction and the specific step in the harvest rate schedule to which the reduction is applied. Small reductions in harvest rates have minimal effects on the probability of meeting survival and recovery standards. Larger reductions in harvest rate can lead to small improvements in the probability of meeting survival and recovery standards (about 0.01 to 0.03), for actions that produce smaller forecasted numbers of spawners (such as A1 or A2). However, at higher levels of forecast abundance (such as under A3) larger reductions in harvest rates can lead to small decreases in the probability of meeting survival and recovery standards (less than 0.03) due to over-escapement, which results in lower levels of recruitment.

Changes in jeopardy probabilities were not sufficient to change the ranking of actions (A3 still produced higher jeopardy probabilities than A1 or A2). The limited set of runs used in this analysis does not allow general conclusions on whether alternative harvest scenarios affect the ability of actions to meet all of the standards. Although the effects of the reductions in harvest rates on jeopardy probabilities are small, they may be large enough to affect the ability of an action to meet the jeopardy standards. This is more likely to occur in situations where average jeopardy probabilities are already close to meeting the standards with the current harvest schedule (e.g., the weighted average 24-year survival probability is close to the standards of 0.7 for all actions; see Table 2.2.4-2). An analysis of all actions with a complete set of runs is needed to fully assess whether the harvest scenarios affect the ability of actions to meet all of the standards.

2b. Harvest rate reductions (fall chinook)

General Result: Alternative ocean harvest schedules were explicitly considered for fall chinook because total harvest rates (which includes a significant ocean harvest on fall chinook) are higher than those on spring-summer chinook and are therefore potentially a more important factor. (We have not yet explored the effects of alternative in-river harvest schedules.) We looked at three ocean harvest scenarios: Current, Conservative (0.85 times current rates), and Liberalized (current harvest rates times 1.15). The 15% change in age specific ocean exploitation rates was based on the latest draft of the U.S. proposal for US v. Canada to the Pacific Salmon Commission (Draft, February 10, 1998). Note that the proposal is based on impacts to age 4 (adult) fish, but we applied the change to all age classes, which results in a greater change from the existing ocean harvest regime. Results suggest that the ocean harvest uncertainties have minor effects on 48-year recovery standards for A2: there is about a 0.025 increase in probabilities under the Conservative scenario, and a 0.03 decrease in probabilities under the Liberal scenario.

3. Sensitivity to recent sources of mortality (i.e., expanded bird populations) (spring/summer chinook only)

General result: The intent in this analysis is to show the effects of explicitly incorporating sources of mortality that may not be reflected in the historical data. The current set of analyses uses historical spawner and recruit data up to brood year 1990 to estimate overall mortality. There are other sources of mortality, however, that may not be reflected in this data. For example, predation on salmon smolts by Caspian terns and other bird predators in the estuary is hypothesized to have increased dramatically in the late 1980's and early 1990's. We considered two alternative ranges of incremental mortality: 5 to 25%, and 10 to 40%.

The simulated effects of an additional mortality affect all actions relatively equally, and thus do not affect the ranking of actions. The maximum decrease in any jeopardy probability for a 5-25% range of additional mortality was 0.15, and for a 10-40% range was 0.23 (both maximum decreases were for action A1, 48-year recovery probability). The smallest decrease was 0.02 with a 5-25% range of additional mortality and 0.05 with a 10-40% range (both for action B1, 100-year survival probability). Insofar as this limited set of runs is representative of the average of all runs (recall that the runs were selected so as to approximate the weighted average jeopardy probabilities over all runs), additional mortality sources do affect the ability of all actions to meet the 24-year survival standard, and the ability of A1, A2, and A2' to meet the 100-year survival standard. However, an assessment of all of the runs is needed to draw this conclusion with confidence.

4. Adult upstream survival rates following drawdown (spring/summer and fall chinook).

General result: Assuming an increase in adult upstream survival rates following drawdown of John Day dam has minimal effects on overall results, for both sets of chinook. For fall chinook, simulations assume on average a two-fold increase in upstream survival with drawdown. PATH needs to carefully scrutinize these conversion rates to ensure the projected survival improvement under drawdown is reasonable.

1.3.8 Experimental Management

An explicit PATH objective is to *assess how future information can distinguish among competing hypotheses, and to advise agencies on research, monitoring and adaptive-management experiments that can maximize learning*. Adaptive or experimental management has been repeatedly recommended by the SRP in their reviews of PATH products and in their recent report (SRP 1998):

> "The weights assigned by SRP members to the key uncertainties reflect the relative likelihood of the alternative hypotheses, based on the evidence currently available. However, all SRP members commented that in some cases, the empirical evidence on which to evaluate alternative hypotheses was poor or lacking. This is because many events have occurred outside of the temporal and spatial range of historic monitoring programs, and outside of our experience. In the face of this level of uncertainty, the SRP felt that it is unrealistic and imprudent to expect irreversible, long-term decisions to recover stocks because there is little confidence that these actions will have the effects they are projected to have. **However, the SRP strongly cautioned that uncertainty should not be used to justify either delaying action or taking no action at all.** Such a misuse of uncertainty in decision-making is not an acceptable component of responsible fisheries management (United Nations Precautionary Approach). Instead, the SRP noted that the existence of uncertainties points to the need to take actions that:
>
> a) result in the best chance at survival and recovery of stocks; and
> b) generate information to reduce uncertainties and improve future decision-making.
>
> Carefully designed and implemented experimental management actions provide that opportunity."

Although PATH has not yet addressed experimental management in depth, PATH retrospective, prospective and decision analyses have helped define key management uncertainties, and have provided a consistent set of data that can be updated and used to evaluate management experiments. Thus experimental management is now a feasible next step, which would add *learning* to the set of criteria already being used to evaluate proposed management actions. Chapter 6 of this report begins the process of assessing the need for experimental management in PATH. We describe what we mean by experimental management, the advantages it provides managers in reducing key uncertainties, how it differs from scientific research, and the six-step cycle that should be followed. We then describe examples of experimental options developed by the SRP and the PATH Planning Group (e.g., changes in the number of hatchery smolts released, in conjunction with A2 or A3), and the steps necessary for the quantitative evaluation of these options. Finally, we list specific PATH objectives related to experimental management for FY 99. The prioritization of all PATH tasks for FY99 will be determined through discussions between PATH and the Implementation Team.